CANMET

METAL RESEARCH ACTIVITIES

PHYSICAL METALLURGY RESEARCH LABORATORIES

PMRL 85-28(TR)

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CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

METAL RESEARCH ACTIVITIES

FY 1985-86

PHYSICAL METALLURGY RESEARCH LABORATORIES

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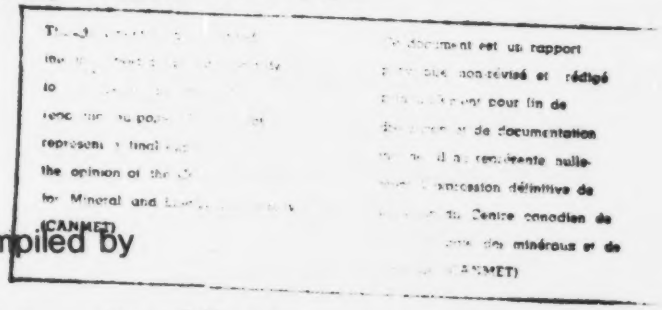

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MICROMEDIA

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FOREWORD

This brochure is an outline of the planned R & D to be undertaken by the staff of the Physical Metallurgy Research Laboratories (PMRL), CANMET, Department of Energy, Mines and Resources during FY 1985/86. The purpose of this document is to make PMRL's research plans known, and to invite responses to it from the private and public sectors alike.

It is estimated that approximately 140 person years of in-house effort will be called for to implement this program. In addition, over 20% of the budget allocated to PMRL will be devoted to contracting appropriate aspects of the program out to the private sector.

To facilitate early publication, project texts have been taken directly from working papers.

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AVANT-PROPOS

Cette publication donne un aperçu des activités de recherche et de développement que les Laboratoires de recherche en métallurgie physique (LRMP) CANMET, Énergie, Mines et Ressources Canada, prévoient entreprendre durant l'année financière 1985/86. Par la publication de ce rapport, les LRMP désirent faire connaître leurs perspectives de recherche et recevoir les commentaires des secteurs privés et public.

On prévoit qu'environ 140 années-personnes seront consacrées à la mise en oeuvre interne de ce programme. En outre, plus de 20 % du budget des LRMP sera affecté au secteur privé pour la mise en oeuvre de certains aspects du programme.

Par souci d'économie du temps, les textes du projet ont été puisés directement des ébauches.

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ADVANCED MATERIALS

RAPID SOLIDIFICATION TECHNOLOGY

Lead Scientist: L.E. Collins
Telephone: (613) 993-7129

Objective

To study the effects of rapid solidification processing on the microstructures and properties of materials, and to develop techniques for producing and consolidating rapidly solidified materials.

Background

Rapid solidification is a new technology which has attracted worldwide attention and is being actively pursued particularly in Japan and the U.S. RST promises potential improvements in a number of material properties in almost all known alloy systems. As yet there has been little development of this technology in Canada and the danger exists that Canadian industry will once more be left behind as new products developed through RST reach the marketplace.

In the past year, Canadian industrial interest in the development of specific alloy systems through RST has been identified, as well as a general need for the development of techniques for the production and consolidation of rapidly solidified alloys.

In the fiscal year 1985-86, the application of rapid solidification to specific alloy systems will be examined in contracted work on stainless steels and metallic glasses, while in-house research will focus on Cu-base alloys for marine applications. Development of processing techniques will be carried out through contracted work on roll compaction, high energy at compaction and laser surface treatments, and in-house development of a melt spinning process for the production of wide strip.

Planned Activity

- Investigate the structure and properties of rapidly solidified alloys.
- Develop techniques for producing and consolidating rapidly solidified alloys.

Monitor contracts to:

- Evaluate the compacting characteristics of rapidly solidified nickel particulates.
- Examine high energy rate compaction as a method of consolidating rapidly solidified metal powders.
- Determine whether the corrosion resistance of conventional stainless steels can be enhanced through rapid solidification.
- Evaluation the corrosion fatigue behaviour of magnetic metallic glasses.
- Conduct a literature survey of rapid solidification technology.
- Design and construct a gas atomizing unit.
- Subscribe to the Battelle study of laser surface modification.

ADVANCED PROCESSES AND ALLOYS

Lead Scientist: R.K. Buhr
Telephone: (613) 993-7148

Objective

To develop and characterize advanced alloys and thin production processes.

Background

Noranda Research Centre has introduced three zinc-aluminum foundry alloys which, for certain applications, compete effectively with cast iron, aluminum, and copper-base alloys. However, optimum procedures for casting the zinc base alloys have not been worked out and the ductility of the alloys is not good. This project has been established to provide backup to the further industrial development of these alloys that will be carried out by Noranda. Foundry characteristics of zinc-aluminum alloys will be determined and guidelines for moulding and casting the alloys will be drawn up; also, the possibility that the ductility and foundry characteristics of the cast alloys can be improved by the addition of small quantities of other elements will be investigated.

As yet there has been little development of rapid solidification technology (RST) in Canada and the danger exists that Canadian industry will once more be left behind as new products developed through RST reach the marketplace. This particular project will be involved with acquisition of equipment, its installation and operation to acquire the necessary expertise to produce RST fibers and sheet for research in other sections.

Existing moulding and core sand "no-bake" binders are either made from organic compounds based on petroleum derivatives or inorganic compounds based on sodium silicate. The petroleum-base compounds have unpleasant and sometimes toxic odours, and are rapidly increasing in cost. The inorganic binders are difficult to shake out after casting and are also difficult to reclaim after use. CANMET has developed a binder made from food acids and limestone that has none of the above disadvantages and can be cured in 30 min by applying a vacuum to the mould.

Planned Activity

- Investigate thermal, dry and wet reclamation of sand bonded with a degradable binder.
- Assess the costs of producing moulds using vacuum curing for degradable sand binders.
- Assess the use of glyoxal as a binder for moulding and core sands.
- Develop non-siliceous binders for investment casting.
- Acquire, install and operate RST equipment.
- Develop the necessary expertise to produce RST fibers and sheet in a variety of alloys for research purposes.
- Determine the accelerated steam corrosion characteristics for Zn-Al alloys modified with Na, Ca and Sr.
- Complete research on the foundry characteristics of modified Zn-Al alloys.

DEVELOPMENT OF ADVANCED MATERIALS AND METHODS

Lead Scientist: W.N. Roberts
Telephone: (613) 993-7120

Objective

To develop and apply state-of-the-art investigative and analytical methodology particularly for characterizing the surface, the microstructure and the state of stress in metals and other materials, and to evaluate the potential and needs in Canada for the surface modification of metals.

Background

Increasingly, progress in research is conditioned by the capability of the equipment available to perform the research, in terms of the kinds of operations the equipment can carry out, the degree (accuracy, resolution, magnification) to which it can perform these functions, and the productivity of the machine. In particular, in the materials field, as elsewhere, the marriage of the computer to scientific instruments has revolutionized their capability in many aspects. It has also added considerably to their complexity. In terms of equipment operation, there are two consequences of this: the period of equipment familiarization is prolonged - usually a one time event - and the demands on operator skill in preparing specimens - if the potential of the instrument is to be fully exploited - are greatly increased. The demands an operator skill in specimen preparation is a continuing thing.

Thus, the nub of this project is equipment familiarization in the first place and secondly, applying the equipment to existing research demands.

To this is added, for the time being, a survey of the industrial interest and needs in Canada together with the research potential in coatings and surface modification of metals and other materials. This evaluation of the current situation will be undertaken in view of the perceived industrial potential of some of the newer coating and surface modification processes.

Planned Activity

Monitor contracts to:

- Develop a neutron diffraction technique to measure residual stresses in welds.

- Develop and apply methods of analyzing anisotropic properties and microstructures in formed metals.
- Develop advanced techniques for analytical transmission electron microscopy.
- Develop and apply techniques for characterizing the microstructures of materials for advanced microelectronic applications.
- Develop familiarity with the operation of the scanning auger microscope (SAM).
- Examine analytical methods for use in research and for application to industrial problems using the scanning electron microscope (SEM) and secondary ion mass spectroscopy (SIMS).
- Assess Canadian interests, needs and research capability in the surface modification of metals and establish an appropriate research program.

CORROSION

CORROSION MECHANISMS

Lead Scientist: R.W. Revie
Telephone: (613) 993-4527

Objective

To investigate the mechanisms of crevice corrosion and pitting corrosion in stainless steels and the corrosion inhibition behaviour of single-component, binary, and multi-component systems of organic inhibitors.

Background

Work in this project is carried out in support of current applied corrosion research and is aimed at shedding light on the basic mechanisms responsible for general corrosion, stress-corrosion cracking, corrosion-erosion, localized corrosion and corrosion inhibition. In this way it is hoped to invest the applied research in other projects with greater insight and understanding.

Planned Activity

- Investigate the efficiency of oxy-anions in inhibiting the corrosion of steels in coal-water slurries.
- Investigate the mechanisms of crevice corrosion and localized corrosion of stainless steels.
- Determine the identity of chemical species at the surface of corroding metals and identify their role.

Monitor contracts to:

- Determine the mechanism of solution and transport of sulphur in Cr_2O_3 and its role in the degradation of stainless steels in coal combustion systems.
- Explore the potential of novel techniques (ion implanation/mixing) to develop oxidation-resistant alloys.
- Determine the phase diagrams for Al-Li-X systems.

CORROSION SERVICES

Lead Scientist: R.W. Revie
Telephone: (613) 993-4527

Objective

To provide services as required for analyses of hydrogen and other gases in metals, to evaluate new methods for controlling the ingress and egress of hydrogen in steels and other alloys; and to carry out failure investigations as appropriate.

Background

The Corrosion Science Section is required from time to time to undertake studies on a cost recovery basis for the private and other sectors. In addition, the section is required to carry out gas analyses needed by the other sections in PMRL. This project is the administrative means of access to these services.

Planned Activity

- Perform and develop improved methods of analyses for hydrogen, oxygen and nitrogen in steels.
- Monitor a contract to determine surface-bound hydrogen/deuterium in high strength steels 1062 and 4037 by secondary ion mass spectrometry.

MATERIALS FOR COAL COMBUSTION TECHNOLOGY

Lead Scientist: J.B. Gilmour
Telephone: (613) 996-4369

Objective

To establish materials performance in fluidized bed coal combustors and solve a number of materials problems identified as potential restraints to the development of large-scale high-temperature energy conversion processes.

Background

The long-term performance and cost effectiveness of materials used for boiler tubes and the like has been identified as a major consideration in coal-fired fluidized-bed combustors for power generation. Under EMR's Oil Substitution Policy, a series of ten tests with a maximum exposure time of 10 000 h of candidate materials is being conducted in Nova Scotia by Nova Scotia Power Corporation (NSPC). PMRL is evaluating the materials tested.

The performance of key materials used in coal gasification and liquefaction processes are also assessed in this project.

Planned Activity

- To evaluate the performance of alloys used for heat transfer tubes in a series of 10 x 1000 h tests in the $1m^2$ atmospheric pressure fluidized bed combustor at Point Tupper N.S.
- Compile and analyze data and observations on the materials degradation in an AFBC fired with sulphur-rich coal and limestone sorbent.
- Study the degradation mechanisms of heat exchanger tubes of the Point Tupper atmosphere fluidized bed combustor (AFBC).
- Monitor a contract to assess the extent of degradation of certain test probes from the EMR-NSPC FBC project.
- Monitor a contract to determine the stress-rupture properties of materials in coal conversion systems.

FOUNDRY TECHNOLOGY

EXPLORATORY RESEARCH AND SPECIAL ALLOY PRODUCTION

Lead Scientist: R.K. Buhr
Telephone: (613) 993-7148

Objective

To determine the fracture toughness of selected non-ferrous and ferrous cast metals, to make this information available to the Canadian foundry industry, and to develop improved understanding of the major factors which determine the fracture toughness of cast metals.

Background

The size, shape and location of flaws or defects in metal structures that can be tolerated under a given set of loading conditions can be defined if certain crack initiation and propagation parameters are known. The basis for such data is related to the fracture toughness properties of the materials as measured by K_{IC} values.

Over the past several years a considerable amount of information on the toughness properties of wrought alloys has been accumulated because of the need to ensure integrity of critical structures, e.g., pipelines, ships, etc. Although knowledge of toughness properties of cast metals is required in certain specific applications, there is a lack of knowledge about the toughness of cast metals, in general. The increasing demands for weight reduction and product safety will inevitably lead to toughness specifications for cast metals in many applications.

Planned Activity

- Produce required special alloys for internal research projects and, on a cost-recovery basis, for externally-sponsored research.
- Determine the static and dynamic toughness properties of selected copper-base alloys used in engineering applications.
- Provide a sophisticated risering scheme for use with a microcomputer.
- Develop new foundry software for use in charge calculations, inventory control and sand control.

MOBILE FOUNDRY LABORATORY

Lead Scientist: R.K. Buhr
Telephone: (613) 993-7148

Objective

To visit a significant number of Canadian foundries and to use the MFL as a base for regional workshops on foundry related topics.

Background

The recent recession has had pronounced effects on the Canadian foundry industry. There has been a large number of the foundries forced to shut down completely, and the vast majority of the remainder have significantly reduced their production and staff. To survive in the current climate requires each foundry to become more competitive, and so technology and technically trained people are more and more in demand.

During the visits of the Mobile Foundry Laboratory, the personnel involved became aware of a need for much greater transfer of current and even past technology to the industry, to ensure they are aware of the best techniques and procedures to follow to improve their competitiveness, increase their productivity and efficiency. Thus, there is a proven need for more workshops on a wide range of topics. Such workshops would be held on a regional basis to reduce the travel needs for those in more remote areas.

Planned Activity

- Visit 33 foundries across Canada.
- Conduct several workshops in different regions of Canada on sand control procedures.
- Hire a consultant to periodically monitor recommendations made to foundries to improve their sand control procedures.

PERMANENT MOULD TECHNOLOGY

Lead Scientist: K.G. Davis
Telephone: (613) 993-7148

Objective

To develop appropriate procedures, die materials and instrumentation for the permanent mould casting of high temperature melting point alloys by gravity, low-pressure, and electroslag casting.

Background

About 90% of all aluminum castings produced in Canada are made in permanent moulds of one form or another. A major problem in low pressure and high pressure permanent mould casting is die life. To overcome this, a technique has been developed by which a disposable mould can be used in conjunction with low pressure casting. If successful, this technique would permit the attainment of high yield at low mould costs, and would also make the process attractive for lower production runs.

The focus of CANMET's research and development on metal casting processes is improved recoveries and casting quality, near net shape, reduced environmental and health and safety problems and technology transfer. Electroslag casting, although limited in applications, appears to offer significant benefits in these areas. At present no commercial facility for electroslag casting exists in Canada. In view of CANMET's strong background in metal casting research and its long and good relationship with the Canadian foundry industry, DND has chosen to provide partial funding for CANMET to undertake the work of extending electroslag casting research to lighter sections and to demonstrate electroslag casting to Canadian Industry.

Planned Activity

- Develop computer programs that model temperature flow in permanent moulds and castings during and immediately after solidification, and evaluate stresses developed.
- Test and evaluate die materials for permanent mould casting by gravity.
- Produce aluminum castings using low pressure disposable mould casting.
- Design and construct LPDMC equipment for high melting point alloys.
- Produce Ni_3Al slab castings using electroslag casting.

PRODUCTION OF ULTRA-CLEAN STEELS

Lead Scientist: A.R. Palmer
Telephone: (613) 993-7076

Objective

To develop the techniques to produce steels to ultra clean specifications for use in research projects.

Background

Experimentation has established the benefits of low residual elements in steel for improved fracture toughness and sulphide stress corrosion cracking in plate grades and improved ductility in plate, strip and sheet grades. The benefits of low residuals and low carbon steels on weldability are also well known. With the advent of modern instrumentation/sensor technology and computer controlled processing the everyday production of these high quality steels has become a critical current and potential feature of international competitiveness in the steel industry. Acquisition of plant facilities for these operations represents a significant capital burden to the Canadian steel industry. It is not surprising that the marginal costs of each reduction in residual level become increasingly disproportionate. Because of a lack of conclusive data on the relationship between steel cleanliness and the properties listed above, there is a need for pilot scale facilities in Canada to produce experimental quantities of steels for joint government-industry-university examination.

Planned Activity

- Develop methods for making ultra clean steels and assess the results in ingots and rolled plate made from these steels.

MARINE MATERIALS

WELD CORROSION

Lead Scientist: R.J. Brigham
Telephone: (613) 995-4860

Objective

To study the weld-related corrosion of ice-breaking ships.

Background

Canada is on the verge of undertaking major multibillion dollar ocean engineering and construction programs: ice-breaking LNG carriers and oil tankers will be built to carry Arctic energy commodities to southern markets; the Canadian Coast Guard fleet is to be expanded by the addition of Arctic class icebreakers; and the Dept. of National Defence is embarking on a major shipbuilding program.

Paint is no longer adequate to protect ships which encounter ice and cathodic protection is generally ineffective with large areas of exposed steel. Thus, corrosion occurs at high rates, particularly in the vicinity of welds, especially with the newer high strength carbon-manganese steels.

Planned Activity

- Evaluate weld corrosion in the PMRL tank test.
- Monitor a contract to evaluate the weld corrosion of a number of steel weld consumable combinations using electrochemical techniques.

HULL STEELS

Lead Scientist: W. Tyson
Telephone: (613) 993-7103

Objective

To contribute to the safety of Canadian shipping by investigating the role of defects and materials as part of the failure analysis of field fractures.

Background

PMRL is frequently asked to participate in failure investigations of fractures in ships by evaluating steel properties, particularly microstructure and toughness. The information is of value not only for the investigation at hand, but also as an item in a record of failures on the basis of which current codes and standards can be reviewed and revised.

Planned Activity

- Evaluate the mechanical properties, microstructure, and composition of ship plate steels currently in Arctic service to provide a data base for developing and applying these steels.

WELDING FOR SHIP CONSTRUCTION

Lead Scientist: R.D. McDonald
Telephone: (613) 993-7114

Objective

To develop welding procedures and evaluate mechanical properties in Arctic ship steel welds, and high strength steels weldments for submarine application.

Background

In the manufacture of Arctic ships there is a need to develop welding process procedures that will provide improved productivity combined with adequate mechanical properties in the weld metal and heat affected zone regions of ship welds.

The Department of National Defence (DND and DREA) are preparing for a major program of submarine construction. As part of a broad program that will be conducted by Canadian industry, government and research institutes on the development of welding technology for the joining of high strength HY80 and HY100 grade steels, PMRL will be involved with the preparation and evaluation of a series of welds prepared in these steels by submerged arc welding. In addition, the heat affected zone structure and mechanical properties will be studied simulating various welding energy inputs in the high strength steels using the Gleeble 1500 weld simulator.

Planned Activity

- Study the effects of weld procedures and consumables on ship plate designed for Arctic service by Gleeble simulation and by a study of the mechanical properties developed by high-energy welds produced by the submerged-arc process.
- Study the properties of weldments in 25 mm thick HY80 steel plate prepared by the submerged arc process.

METAL FORMING

FORMABILITY AND PROCESSING OF SHEET STEELS

Lead Scientist: A.F. Crawley
Telephone: (613) 993-7136

Objective

To assist the Canadian metal forming industry to process new types of "narrow specification steels" (continuous annealed, plain carbon, high strength low alloy, and dual phase) by contributing to the understanding of the influence of the metallurgy and processing on ultimate formability.

Background

The sheet metal industry in entering an era of new challenge and competitiveness in an essentially mature market. The automotive industry, the major user of sheet steel, has begun to demand strict quality assurance from its suppliers. Other industries will probably follow suit. Fabricators must, therefore, operate with a better understanding of formability and metal flow in order to meet dimensional tolerances and reduce material wastage through failures. With its expertise in metal processing and characterization, formability testing and analysis of metal flow behaviour, CANMET is uniquely placed to provide the required knowledge to assist in this transition.

Planned Activity

- Determine the forming behaviour of aluminum killed drawing quality sheet and microalloyed sheet after the short term recrystallization processing of a galvanizing line and thereby to optimize processing.
- Develop techniques, procedures and computer programs for the determination of formability parameters and to monitor deformation flow as a function of strain path.
- Conduct a review on the capability of predicting physical properties and of metallurgical design through manipulation and control of process variables.
- Monitor a contract to determine the influence of frictional and microstructural effects on the formability and press shop performance of galvanized steels.

NEAR NET SHAPE FORGING

Lead Scientist: A.F. Crawley
Telephone: (613) 993-7136

Objective

To develop forging techniques which reduce materials and energy consumption by developing an understanding of the interplay of metal flow and microstructural characteristics in the forging process.

Background

Near net shape (NNS) forging provides the opportunity to effect materials savings by reduction in waste (flash), energy savings by reduction in processing steps and economic advantages by elimination of finish machining. NNS technology has hitherto been applied to very specialized and expensive materials. Advantages, however, will accrue to those companies which can apply a form of this technology to more common materials in high production rate processes.

The technical issues are complex because material flow is inherently non-uniform and influenced by strain rates and degrees of microstructural change.

Highly sophisticated software has been developed for computer aided designs (CAD) of dies and computer aided manufacturing (CAM) of forgings for high technology applications. This software is expensive and requires a large computer which the vast majority of forging companies do not have, far less the expertise. There is a need to develop modified programs which can be run on a small computer which are within the capability of small companies.

Planned Activity

- Develop techniques to assess the forgeability of steels and to determine the forgeability of conventional heat treatable steels and new microalloyed steels.
- Develop a finite element code to model deformation processes and apply the code to study the local strain and grain structure changes in hot forming.
- Explore the possibilities of developing CAD/CAM programs with finite element capability, which can be used on small computers for die design.
- Develop procedures to compact rapidly solidified metals. This work will be in support of a project directed from the Metallurgy Section.

Monitor contracts to:

- Complete the design to upgrade the 500 t press.
- Conduct a study on forgeability based on local strain measurements and grain structure changes.

ROLLING MILL PROCESSING TECHNOLOGY

Lead Scientist: A.F. Crawley
Telephone: (613) 993-7136

Objective

To develop rolling mill processes for modern high quality steels based on the optimum utilization of current Canadian facilities and to demonstrate new technological opportunities by designing schedules incorporating thermomechanical processing, interrupted cooling and in-line post rolling control of cooling and by developing a fundamental understanding of the stress-strain characteristics and the metallurgy of the deformation zone.

Background

In order to maintain its market share and competitiveness, the Canadian steel industry must meet demands for steels of high quality and consistency, high strength and toughness, in a range of thickness gauges for pipeline, offshore structures and Arctic vessels. For optimum use of current and future rolling facilities a basic understanding of the deformation process and influence of accelerated cooling are essential. Because of the large masses of material and high temperatures involved it is extremely difficult to gain accurate information on the metallurgy and mechanics of roll gap deformation. By judicious experimentation, application of rolling theory and highly sophisticated mathematical techniques such as finite element analysis, insight into the process is attainable. From such information, rolling schedules can be developed and tested on the PMRL rolling mill which is the only such facility in Canada. Based on earlier correlations with industrial mills, schedules can be developed for commercial processing.

Planned Activity

- Using the cam plastometer assess rolling theories for prediction of strip rolling schedules.
- Determine the high temperature flow stresses of Ti-V and Ti-N steels using the cam plastometer and apply the data to simulate strip rolling schedules.
- Develop rolling processes for modern high-strength and tough steels.
- Determine the effects of inhomogeneities in through-thickness deformation on prediction of mill power and load requirements and microstructural development.

- Evaluate the technology for on-line accelerated cooling of microalloyed steel plate as a function of composition.
- Plan and prepare a third CANMET seminar on Rolling Mill Processing.
- Conduct rolling and heat treatment processing as requested by scientists involved in research.
- Conduct metal deformation tests on a cost recovery basis.
- Develop modified 4130 compositions and post-forming heat treatments to produce tubular steels with increased yield strength and high SSC resistance for sour-downhole service.

Monitor contracts to:

- Evaluate by simulation experiments the hot ductility properties of continuously cast steel in production and subsequent controlled rolling.
- Determine the effect of boron on precipitations and recrystallization kinetics in Ti-bearing linepipe steels.
- Determine the predictive capabilities of models of strip rolling in terms of accuracy and consistency.

MICROSTRUCTURE AND ANALYSIS

CANMET PORTABLE X-RAY STRESS DIFFRACTOMETER

Lead Scientist: R.A. Holt
Telephone: (613) 993-7085

Objective

Develop and complete evaluation of the experimental/engineering model of the CANMET Portable X-ray Stress Diffractometer and apply the diffractometer to the measurement of stress in real engineering components and structures in support of the continued development of a commercial diffractometer to measure stress nondestructively.

Background

It is important for many purposes to know what stresses are present in engineering structures. Aircraft, ships, pipelines, and nuclear reactors are some obvious examples of such structures. Load limitation, routine inspection, product acceptance, public safety, design evaluation, retirement from service, need for stress relief, are some of the reasons one would want to know the stresses present in a structure.

Stresses can be determined by several methods' strain gauges and X-ray diffraction being the most common. Although strain gauge methods can be applied in the field, they are time consuming and depend on drilling or otherwise removing material from a structure. X-ray diffraction offers a nondestructive means of determining surface stresses, although until recently, mobile equipment had not been developed for the purpose. The instrument developed in PMRL/CANMET is error compensating and is designed to measure surface stresses at one spot in a structure or specimen from one reading of 1-2 minute duration.

Planned Activity

- Evaluate and improve the experimental model.
- Provide advice and assistance in the continued development of the commercial prototype.
- Develop a miniature X-ray tube and H.V. cable for the portable stress diffractometer.
- Upgrade the experimental model as required.
- Process patent applications concerning the portable diffractometer.
- Develop in Canada, a source of position sensitive X-ray detectors based on solid state arrays.

MICROBEAM AND X-RAY ANALYSIS

Lead Scientist: W.N. Roberts
Telephone: (613) 993-7120

Objective

To cooperate with other sections in PMRL, other government agencies, industry, and the universities in providing services in X-ray analysis and analytical microscopy.

Background

The resources in electron microscopy (TEM, TEM/STEM and SEM), microprobe analysis and X-ray diffractometry operated by the Physical Metallurgy Research Laboratory are to be found in the Metal Physics Section and are accessed through this project. Plans are in hand to add secondary ion mass spectroscopy (SIMS) to this capability in 1986-87.

These resources, in terms of expertise and equipment, contribute regularly to PMRL research. In addition, they are also made available, as required, to other government agencies, industry and the universities on a cooperative basis appropriate to the circumstances, including cost recovery.

Planned Activity

- Provide support for projects on control and prevention of corrosion and erosion.
- Carry out microanalysis and characterize the microstructures of simulated heat affected zones of microalloyed steels.
- Analyze and characterize the microstructure of engineering alloys and correlate with mechanical properties.
- Characterize the microstructures of cast Ni-Al and Mn-Ni-Al bronzes and relate the results to toughness properties.
- Develop techniques in transmission electron microscopy for characterizing the microstructure of rapidly solidified alloys.
- Conduct microbeam analysis re research on copper anodes, fluidized bed reactors, hydrocracking reactor overlays.
- Provide microbeam and X-ray analysis services as appropriate.

MICROSTRUCTURE AND PROPERTIES OF STEELS

Lead Scientist: M.J. Godden
Telephone: (613) 993-7129

Objective

To characterize the microstructures, determine microstructure-property relationships, and use this knowledge to develop improved steel products.

Background

Advances in steel production, fabrication and application technology are made primarily through understanding microstructure property relationships and developing improved properties by an ability to manipulate the microstructure as a result of this understanding. This project seeks both to identify the fundamental relationships between microstructure, phase transformations and properties, and to exploit known and developing relationships in specific steel product applications.

Microalloying steels are an emerging class of structural steels which will be widely used in the future. Until now, they have been mainly used for linepipe and some automotive sheet applications. However, microalloy steels are currently being developed for structural plate, ship plate, bar, forgings, rail and castings. Research is needed on the fundamental microstructure-property relationships in these steels, and on the evolution of microstructure during processing. The microstructures are complex, and the important properties of strength, toughness, and formability are determined by fine-scale mechanisms which must be studied by high-resolution electron-optical techniques.

Modern techniques for hot-metal treatment and steel-ladle treatment produce exceptionally low concentrations of S, P, O, H and N, with corresponding improvements in properties for products such as linepipe, structural plate, pressure vessel steels and oil country tubular goods. To enable users to specify appropriate residual levels for different products, it is necessary to characterize the type and distribution of non-metallic inclusions and residual elements in various steels, and correlate with properties of interest.

Specific steel development projects include on-line-accelerated-cooled (OLAC) line-pipe steel, ultra-low-carbon-bainitic (ULCB) line-pipe steel, thermomechanically treated ship-plate steel, and premium rail steel.

Planned Activity

- Study the mechanisms that control microstructure during thermomechanical processing of microalloyed steels.
- Study the relationship between mechanical properties and microstructure of microalloyed steels.
- Develop and apply techniques of analytical electron microscopy to the quantitative analysis of microstructure in steels.
- Develop techniques of automatic image analysis and carry out quantitative microstructural characterization of steels.
- Develop improved plate steels for linepipe, ship hulls, and offshore structures.
- Characterize hydrogen-induced blister cracking in electric resistance welded pipe.
- Examine the microstructural effects on disbonding of stainless steel weld overlays in hydrogenation reactor vessels.
- Determine the microstructure, wear properties, and weldability of commercial and experimental rail steels, and prepare a monograph on rail steels.
- Summarize the compositions and properties of current steel suitable for icebreaker propellers.
- Carry out cost recovery investigations for external organizations and provide technical support to other sub-sub-activities.
- Develop techniques of bulk quantitative elemental analysis for low-residual steels.

Monitor contracts to:

- Assess ULCB-HSLA steels with particular reference to the steelmaking capability of Canadian industry.
- Examine the metallurgical factors that control the machinability of medium carbon steels.

STRESS ANALYSIS

Lead Scientist: G. Roy
Telephone: (613) 993-7083

Objective

To develop and maintain expertise in analytical and numerical stress analysis for application to practical problems such as the determination of residual stresses in weldments.

Background

Residual stresses in welded structures can cause fracture-related events such as "pop-ins", which may initiate long running cracks in pipelines, offshore structures, etc. It is therefore important to be able to predict (through understanding of the causes of residual stresses) and to measure (by such techniques as hole drilling) the magnitude of such stresses.

Planned Activity

- Evaluate the hole drilling method for residual stress measurements in mild steel and stainless steel.
- Measure residual stresses in single and multipass welds.
- Monitor a contract to predict residual stress distribution in single and multipass welds by the finite element method.

NONDESTRUCTIVE TESTING

CERTIFICATION OF NDT PERSONNEL

Lead Scientist: V. Caron
Telephone: (613) 993-7105

Objective

To certify NDT personnel on a national basis in accordance with CGSB standards, and to prepare draft international standard.

Background

The significance of NDT Technology reflects national concern for the public safety related to the integrity of engineering structures (nuclear plant, offshore rigs, pipelines, etc.); product quality and the associated productivity and competitiveness of the producer. The self-regulation of the industry using NDT is achieved by certification of NDT personnel to industry set standards. Since 1960, PMRL/CANMET has been acting as the certifying agent operating in co-ordination with the CGSB Committee on NDT Certification. Test centres for industry personnel have been established across Canada and both the Canadian Society for Non-destructive Testing and its Foundation are involved in providing training courses for certification purposes.

The secretariat activity for ISO TC135/SC7 involves drafting an international standard for the certification of NDT personnel.

Planned Activity

- Certify NDT personnel on a national basis in accordance with CGSB standards.
- Draft international standard (ISO).

NDT TECHNOLOGY DEVELOPMENT

Lead Scientist: V. Caron
Telephone: (613) 993-7106

Objective

To contribute to the development and application of nondestructive testing technology in both research and industry.

Background

As metallurgical processing technologies become more refined in the areas of on-line quality control and statistical process control, the reliance on, and requirement for, sensors and non-destructive test procedures becomes more urgent.

On-line temperature measurement, product sizing, defect detection and sizing are candidate areas for instrumentation development and characterization using the existing technology base of ultrasonics, eddy current, infrared measurement systems.

In addition, the use of lasers, fibre optics, noise thermometry, computerized defect pattern recognition, are active areas for technical development.

Planned Activity

- Develop remote ultrasonic sensors for on-line NDT inspection of metal (steel) products for defects and property determination. (Joint project with the Industrial Materials Research Institute, IMRI).
- Develop techniques to size and monitor defect growth in electric resistance welded (ERW) pipes.
- Monitor contracts for further testing of an acoustic emission prototype for on-line defect detection during welding of thick-walled pressure vessels.
- Study interaction of stress and magnetization for linepipe stress monitoring and for developing the relevant theory. (Joint project with IMRI).

NON-FERROUS METALS

CAST NON-FERROUS ALLOYS

Lead Scientist: J.D. Boyd
Telephone: (613) 993-7129

Objective

To characterize microstructures and determine microstructure-property relationships in cast non-ferrous alloys, and to use this knowledge to develop improved products.

Background

In response to shifts in policy, Canadian ships, particularly ships of the Coast Guard services are penetrating further into ice infested waters on extended shipping seasons. As a result, equipment is being tested beyond limits for which it was originally intended. Ships' hulls are being breeched, propeller shafts bents and propellers broken. Among other things, the high strength corrosion resistant copper base alloys from which propellers are cast are being reevaluated. Nickel-aluminum bronze and Mn-Ni-Al bronze propeller alloys deserve particular attention so that improved alloys or treatments can be identified.

Noranda Research Centre has introduced three zinc-aluminum foundry alloys which, for certain applications, compete effectively with cast iron, aluminum, and copper-base alloys. However, optimum procedures for casting the zinc base alloys have not been worked out and the ductility of the alloys is not good. Thus, this project has been established to provide backup to the further industrial development of these alloys.

Planned Activity

- Document the mechanical properties of Mn-Ni-Al bronze propeller alloys, identify failure mechanisms, and develop improved alloys and processing practices.
- Monitor a contract to document the fracture, fatigue, and corrosion fatigue behaviour of Mn-Ni-Al and Ni-Al bronze alloys and identify the microstructure associated with each failure mechanism.
- Determine the microstructure, mechanical properties and corrosion behaviour of Zn-Al foundry alloys, modified with trace alloy additions.

WROUGHT NON-FERROUS ALLOYS

Lead Scientist: J.D. Boyd
Telephone: (613) 993-7129

Objective

To characterize microstructures and determine microstructure-property relationships in wrought non-ferrous alloys, and to use this knowledge to develop improved products.

Background

The Canadian non-ferrous metals industry faces challenges which at best will force significant departures from traditional processes and products, and at worst will threaten the existence of many mining and manufacturing operations. On the mining side, the challenge is severe price competition from new operations in developing countries, and on the manufacturing side the challenge comes mainly from the substitution of non-ferrous metal components by non-metallic materials. Examples of these are SiO_2 optical fibers replacing Cu wire, B-epoxy and C-epoxy fiber-reinforced composites replacing high strength Al alloys, plastics replacing Al and steel sheet components in automobiles, injection-moulded plastics replacing Al- and Zn-base die castings, and intermetallic compounds, ceramics and ceramic-matrix composites replacing Ni-base alloys in advanced turbine engines. There is a need for a strong effort by the non-ferrous metals industry to develop new alloys which can compete for some of these applications. With the exception of the Al industry (Alcan), the Canadian non-ferrous metals industry concentrates research mainly on mining and extractive metallurgy, whereas its research product development is comparatively modest. Thus, the work of government research laboratories and universities represents a large part of the national effort in non-ferrous physical metallurgy.

Planned Activity

- Determine Li distribution in commercial and experimental Al-Li alloys by electron energy loss spectroscopy.
- Develop and apply techniques of analytical electron microscopy to the quantitative analysis of microstructures in non-ferrous alloys.
- Conduct cost recovery investigations for external organizations, and to provide technical support to other sub-sub-activities.

OFFSHORE STRUCTURES

FATIGUE AND FRACTURE CONTROL IN OFFSHORE STRUCTURES

Lead Scientist: O. Vosikovsky
Telephone: (613) 993-7083

Objective

To develop a Canadian expertise and data base on the fatigue and fracture resistance of materials and weldments for use in offshore structures.

Background

The quest for national self-sufficiency in hydrocarbons, particularly oil, will lead to the early development of offshore resources in Hibernia and the Beaufort Sea. Development of the gas deposits on the Scotian Shelf will also continue. The prospect calls for many initiatives in the federal government. Among these is the need to ensure that there is an awareness in the public sector of the role of materials in the construction and service performance of platforms and rigs, submarine pipelines and other special marine requirements. The reason is twofold. First, to ensure that regulations concerning materials selection and performance are well conceived. Second, to take initiatives and provide support to ensure that Canadian industry profits to the extent possible from the industrial opportunities that offshore oil development will present. The need for a government presence in this play is also twofold. First, it arises from the fact that much of the current offshore technology was developed for the North Sea oil and gas deposits and must be further adapted for Canadian conditions in such a way as to safeguard health, safety, and the environment. Second, the technology is in the hands of non-Canadian multinationals. Thus, in the national interest, there is considerable scope for a federal presence in materials research and development.

Planned Activity

- Study the corrosion fatigue of welded joints.
- Evaluate toughness of high-cleanliness steels in transition temperature range.
- Relate toughness to microstructure by quantitative models.
- Examine the effect of notch sharpness on Charpy impact transition.

Monitor contracts to:

- Evaluate current techniques for repairing cracks in tubular joints in terms of the effect on fatigue life.
- Determine the stress intensity factors for weld defects.
- Fabricate welded tubular joints and evaluate their performance in fatigue.
- Fabricate and evaluate welded structures in marine environments.

STRUCTURAL INTEGRITY MONITORING OF OFFSHORE STRUCTURES

Lead Scientist: V. Caron
Telephone: (613) 993-7106

Objective

To develop and evaluate inspection and monitoring systems for defect detection and characterization in Offshore Structures.

Background

Platforms and drill rigs operating in Canada's offshore regions will be subject to extreme in-service conditions-high seas, ice and cold temperatures at Hibernia; very cold temperatures and high ice forces in the Beaufort Sea. Current practice for detecting and monitoring growing cracks in offshore structures in more temperate climates must be evaluated for application in Canada to ensure that our inspection systems and divers have the most suitable technology available. Automated NDE techniques for remote operation are of particular interest in our harsh environment. CANMET resources will be used to develop appropriate NDT equipment and practices for underwater use.

Planned Activity

- Investigate eddy current for underwater use.
- Investigate crack transparency of ultrasonic signals.
- Investigate application of ultrasonics to the inspection and evaluation of girth welds.
- Investigate flaw visualization in heavy section weldments using acoustic imaging.
- Study the application of ultrasonics to underwater inspection of offshore structures.

Monitor contracts to:

- Design and construct a computer controlled two-dimensional acoustic array for beam steering in offshore structures.
- Take measurements of acoustic pressure of sound waves.
- Develop NDE methods for characterizing defects in heavy sections.

WELDING TECHNOLOGY FOR OFFSHORE STRUCTURES

Lead Scientist: J.E.M. Braid
Telephone: (613) 992-6395

Objective

To evaluate the fracture properties of welded joints for offshore structures.

Background

The development of Canadian offshore resources requires that offshore structures such as drilling and production platforms and pipelines have welded joints with high fracture resistance. A program is underway to evaluate the effect of weld process and welding consumables on fracture toughness properties of welded joints prepared from selected steels.

Planned Activity

- Evaluate currently available welding consumables for use in offshore structure fabrication and identify areas where toughness may be improved.
- Determine the role of residual stress and distortion on the fracture resistance of welded joints.

Monitor contracts to:

- Provide data relating steel composition and quality to HAZ toughness in order to give guidance when good HAZ toughness is required in thick section steels.
- Evaluate the suitability of currently available flex cored arc welding consumables for fabrication of offshore and Arctic structures.
- Fabricate butt and Tee joint weldments using the shielded metal arc welding process to provide CANMET with test specimens as part of the evaluation of materials for offshore structures.
- Evaluate the potential of the pulsed gas metal arc welding process for the all-position, mechanized and automated welding of offshore oil and gas installations and Arctic vessels.
- Investigate the fracture toughness of the HAZ and weld metal for three selected steels over a range of heat inputs.

PIPELINES

INTEGRITY OF LINEPIPE

Lead Scientist: K.C. Wang
Telephone: (613) 993-7104

Objective

To enhance the security of pipeline systems by establishing quantitative limits for accepting defects in linepipe and by measuring dynamic toughness of linepipe steels.

Background

There is a large capital investment in pipelines in Canada. Current replacement cost is estimated to exceed $100 billion, so there is much to be gained by maximizing pipeline life. One of the major causes of pipeline failure is mechanical damage. Dents, scrapes and gouges can be inflicted externally during pipeline laying and subsequently, pipelines can be damaged by third parties operating on the pipeline right-of-way. There is a need to assess how much damage pipelines can safely tolerate before fracture initiates in pipelines.

The experience gained in defect assessment of conventional sub-arc welded pipe will be used to assess ERW pipe, which could be a more economical alternative for many applications.

Planned Activity

- Develop instrumented impact testing methods to evaluate the dynamic fracture resistance and crack arrest properties of structural and linepipe steels.
- Provide baseline data for inspection of welds in electrical resistance welded pipes and for inspection standards for pipelines containing mechanical damage.

STEELS FOR OIL AND GAS PRODUCTION AND TRANSPORTATION

Lead Scientist: R.W. Revie
Telephone: (613) 993-4527

Objective

To characterize the stress-corrosion cracking and hydrogen damage behaviour of Canadian-produced line pipes and define the variables influencing corrosion of Canadian-produced oil country tubular goods.

Background

With the depletion of sweet petroleum deposits, sour wells are being developed. This trend increases the likelihood of pipe failure from sulphide stress cracking caused by H_2S. Further, in enhanced oil recovery operations, combinations of CO_2, H_2S, and moisture produce highly corrosive environments. Predictability of the corrosion resistance of equipment used in all these systems is important if the processes are to be run safely and efficiently, without extensive downtime caused by unexpected corrosion failure. Improved corrosion resistance may be possible through the use of inhibitors as well as by optimizing the compositions and thermomechanical treatments of alloys specified for these applications.

Planned Activity

- Develop a slow strain rate technique for determining SSC susceptibility and assess SSC behaviour of commercial seamless oil country tubular goods (OCTG) in simulated down-hole sour environments.
- Conduct a literature survey on SSC resistance of 4130 steels.
- Review the literature on use of inhibitors for enhanced oil recovery operations in Canada, identify corrosion related problems and formulate an R & D strategy to address them.
- Monitor a contract to characterize the corrosion behaviour of seamless and ERW oil country tubular goods by CO_2.

WELDING

DEVELOPMENT OF NEW WELDING PROCESSES

Lead Scientist: R.S. Chandel
Telephone: (613) 993-7109

Objective

To develop and evaluate new welding processes for the fabrication and repair of engineering structures such as pressure vessel, offshore structures and pipelines.

Background

The fabrication of engineering structures such as large pressure vessels for the petrochemical industry and offshore drilling and production platforms requires the development of advanced welding processes. For example, welding of thick section steels, i.e., 100 mm and greater requires the development of narrow gap welding technology. Weld overlay techniques are required for applying stainless steel lining to petrochemical reactor vessels.

A study of repair and reclamation technology in Canada has shown that the need for such technology is diffuse and in many cases poorly documented. Because of the role that mining plays in Canadian economy, the initial focus of a project has been on the repair of cast iron components in mining machinery. The project has used the case study approach to gather data on (1) the uses of cast iron in mining equipment and (2) repair and downtime costs. Based on this data research work is being carried out to determine optimum procedures for the repair of cast iron components of mining equipment.

The application of high powered laser (20 kw) technology and the development of the gas metal arc/submerged arc combination process to the welding of land base and offshore pipelines are being investigated under contract to industry. Experimental welds in a range of pipeline steels are being produced.

Planned Activity

- Develop overlay technology by using electroslag strip overlay process.
- Establish the relationship between weld process variables and wire feed speed for submerged arc welding (SAW) process.
- Evaluate the effect of gap width and heat input for SA516 and LT60 weld metals.

- Prepare literature survey on the principal and industrial application of friction welding.

Monitor contracts to:

- Study the repair and reclamation of cast iron.
- Evaluate and develop the gas metal arc and submerged arc combination process for application where improved weld joint toughness is required.
- Evaluate the factors controlling notch toughness and distortion of narrow gap welds.
- Using the gas metal arc narrow gap welding process, evaluate the effect of weld process parameters on the quality structure and properties of heavy section welds in pressure vessel steels.
- Study relationship between welding parameters and wire feed speed.
- Develop stainless steel cladding technology for heavy wall pressure vessels.
- Evaluate the structure and properties of weld overlay subjected to hydrogen disbonding treatment.
- Study the factors relating to solidification cracking of SAW weld metal.

THERMAL-MECHANICAL SIMULATION OF WELD PROCESSES

Lead Scientist: J.T. Bowker
Telephone: (613) 993-7109

Objective

To simulate metallurgical processes such as continuous castings, welding and hot rolling using the Gleeble simulator.

Background

The improvement of metallurgical processes such as continuous casting, hot working and welding may require costly production trials to develop new operating procedures. The Gleeble 1500 thermal/mechanical simulator, which can simulate the thermal/mechanical operations involved in many of these processes, can be used to determine the effects of changes in process operating parameters.

The information gained from these laboratory based studies can be implemented into full scale production procedures.

At present, 4 cooperative programs with Canadian industry and universities are underway to simulate continuous casting of steel and the heat affected zone region of steel weldments.

Planned Activity

- Study the factors that control the ductility of continuous cast steels in the temperature range 700-1100°C.
- Simulate various regions of the heat affected zone for a range of microalloy steels.
- Assess the effect of nitrogen on heat affected zone (HAZ) toughness.
- Monitor a contract to conduct finite element analysis modelling of weld thermal cycles, grain growth and precipitate dissolution.
- Monitor a contract to identify precipitates in the real weld and simulated HAZ for a range of offshore steels.

OTHER

COST RECOVERY AND MECHANICAL TESTING

Lead Scientist: W. Tyson
Telephone: (613) 993-7103

Objective

To perform routine mechanical testing required for other projects, and to provide services not otherwise available to outside organizations.

Background

The mechanical properties of metals, especially their strength and toughness, are the primary determinant of their structural uses. It is, therefore, essential to measure these properties for new materials. This project recognizes the ongoing demand for mechanical property measurement, and encompasses development of new techniques of measurement such as CTOD testing which regularly emerge from research and are standardized by such bodies as the ASTM.

Planned Activity

- Provide services and facilities for mechanical testing and evaluation.
- Install CTOD routine test facilities for specimens up to 30 mm thick.
- Provide consultative and investigative services on a cost recovery basis in matters relating to materials structure, materials properties and service behaviour.